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# Opportunities and challenges in setting up solar photo voltaic based micro grids for electrification in rural areas of India

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ABSTRACT

Rural area electrification in developing countries helps to improve the quality of life of the people. It increases productivity and supports education. It also discourages people from migrating towards urban areas. In India about 70% of the population lives in rural area, hence it is necessary to electrify these villages to achieve inclusive economic growth. Transmission and distribution of power to this less densely populated areas which are located far away from the power generating stations is the major reason for not able to achieve 100% electrification in the country. Hence it is necessary to find out an energy source which can be decentralized to supply power to these hamlets. As India is blessed with solar energy which is omnipresent in almost all parts of the country, micro grid system which uses solar photo voltaic panels seems as the finest option. The solar photo voltaic system converts light energy into direct current power using photovoltaic effect. Battery is used to store the extra power generated during the day and used during nights. Inverters and power conditioning devices are used to convert direct current power generated by solar photo voltaic systems to alternative current, which is supplied to the load using power distribution network which adds to system cost. At present the capital cost and the land requirement for this system is higher than all other renewable energy power generation system. But it has very less operation and maintenance cost which makes it superior to other system. Moreover additional modules can be added to it when the power demand increases. This paper says about how rural area electrification can be achieved in India by solar photo voltaic system micro grid system and the challenges which has to be over come during implementation.



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*Abbreviations:* RE, renewable energy; SPV, solar photo voltaic; PV, photo voltaic; LT, low tension; R&D, Research and Development; PDN, power distribution network; PCU, power conditioning unit; BMS, battery management system; DC, direct current; AC, alternating current; APC, active power curtailment; JNNSM, Jawaharlal Nehru National Solar Mission; RGGVY, Rajiv Gandhi Grameen Vidyutikaran Yojana; SIPS, Special Incentives Package Scheme; CERC, Central Electricity Regulatory Commission; BPLHH, below Poverty Line House Holds; NTPC, National thermal power corporation; REC, Renewable Energy Certificate; RPO, Renewable Purchase Obligation; SHS, solar home system; MNRE, Ministry of New and Renewable Energy.

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## 1. Introduction

In India more than 80,000 villages and about 450 million people do not have access to electricity [1]. Many villages connected to the grid are constantly under blackouts due to uncertainties of power supply. Erratic voltage levels and unreliable power supply are major problems, due to the inadequate generation and ageing transmission system leading to frequent power cuts. About 20–40% of power is lost during transmission and distribution in India, which is very high when compared to other countries [2]. The extension of grid to remote villages will cost around 1/kWh/km of grid expansion [3]. Moreover when these villages are electrified by using conventional energy source like coal it will add further to global warming of earth because of the emission of green house gases, India already accounts for 4% of global carbon dioxide emission [4]. Hence it is necessary to find out an energy source which not only satisfies the energy demand of the people but also is eco friendly. Solar and wind energy are one such forms of energy. Since wind is highly unconditional and most of the wind energy in India has been harvested, solar power emerges as a viable option. Moreover India is a country were solar energy is available almost during 300 days of a year. Theoretically India's solar power reception on its land area is about 5000 trillion kWh/year and average solar energy reaching India daily varies from 4 to 7 kWh/m$^2$ with about 2300–3200 sunshine hours per year, depending upon location. This is very high when compared to the current total energy consumption. Hence solar photovoltaic energy based decentralized power system is a viable option for the electrification of remote villages as reflected in different case studies [5–7]. Many such renewable isolated power plants of 1–20 kW capacity are working consistently in India supplying electricity to remote villages, mainly for lighting for duration of 4–5 h [7]. In November 2009, government of India has approved the Jawaharlal Nehru National Solar Mission (JNNSM), which creates favorable conditions for quick renewable energy (RE) diffusion across the country. This project aims to produce 20,000 MW of energy using solar power within the year 2022. In December 2010 a 5 MW photovoltaic grid interactive solar power plant has been established on 263,045.9 m$^2$ in Rettai Pillai Ayyanarkoil, in Sivagangai district as a part of this mission. A 30 MW solar photovoltaic power plant is about to be commissioned at Patan district in Punjab on July 2011. At present 8% of India's energy demand comes from renewable energy of 70% comes from wind energy [8], this share is expected to dominated by solar power in the upcoming years.

The use of solar photo voltaic system to electrify rural areas has both social and economic benefits. The power generated using this system can be used to operate motor and pumps used for irrigation, storing consumable agricultural products, and many other usages. As for the social benefits are concerned electricity allows school going children to study at night, women to do some entrepreneurial activity and so on; it contributes to better health as it allows switching from inferior biomass fuels to clean electricity thereby enhancing indoor air quality [9]. It also gives rural people lot of opportunities to get access telecommunications and mass media [10]. It also helps to reduce carbon footprint and minimize the fossil fuel consumption. In India for many decades rural electrification has been an important policy agenda for both the central as well as the state governments. In the early periods, governments focus was placed mainly on the electrification of irrigation pumps for raising agricultural productivity [11]. This was particularly so when the green revolution took off in the late 1960s. However, there has been a change of direction toward more social purposes as rural electrification has started to assume social roles. At the time of independence in 1947 only about 1500 villages were electrified in the country [12]. By the end of March 2010, close to 500,000 villages in India, 84% have been electrified. In particular, the number of electrified village has increased rapidly in recent years due to the government's effort under the accelerated rural electrification program and initiatives for "inclusive growth", which aims at both rapid growth and providing social justice. More than 70 thousand villages in the country were electrified from 2005–2006 to 2009–2010 [12].

## 2. Review of the technology and its suitability in rural areas

### 2.1. Solar photovoltaic system

To explain the photovoltaic solar panel in simple terms, the photons from the sunlight knock electrons into a higher state of energy, creating direct current (DC) electricity. Groups of PV cells are electrically configured into modules and arrays, which can be used to charge batteries, operate motors, and to power any number of electrical loads. With the appropriate power conversion equipment, PV systems can produce alternating current (AC) compatible with any conventional appliances, and can operate in parallel with, and interconnected to the utility grid. The efficiency of this system is about 4–40% depending upon the material used for construction of PV arrays. The PV arrays made up of mono crystalline converts 15% of solar power reaching its surface into electricity, while multi crystalline converts only 12% of solar power reaching its surface into electricity this percentage further drop down to 6% and 4% in case of amorphous silicon cells (also called as thin film PV cells), cadmium telluride and copper indium PV cells. The efficiency of the cell increases with increase in cost of the PV arrays [13]. Recent development in PV technology has led to a development of high efficient PV arrays know as multi-junction PV, which operates at an efficiency of 40% [13]. The efficiency of the PV arrays can be improved by 30–50% by using 2 axis solar tracking system in sunny days and by 50% by using horizontal axis orientation instead of 2 axis solar tracking system during cloudy days [14]. The efficiency of the material can be further improved my using mirrors and lens to concentrate solar rays into PV arrays [15,16].

Regardless of size, a typical silicon PV cell produces about 0.5–0.6 V DC under open-circuit, no-load conditions. The output of a PV cell depends on its efficiency and surface area, and is proportional to the intensity of sunlight striking the surface of the cell. For example, under peak sunlight conditions, a typical commercial PV cell with a surface area of 160 cm$^2$ ($\sim$25 in.$^2$) will produce about 2 W peak power. If the sunlight intensity were 40% of peak, this cell would produce about 0.8 W. The components of a standard the solar system are PV module, junction box, mounting structure, inverter, battery, charge controller, combine box. Photovoltaic cells are modular. That is, one can be used to make a very small amount of electricity, or many can be used together to make a large amount of electricity. A 3.9-in. (10 cm) diameter PV cell can make about 1 W of power if the sun is directly overhead and the conditions are clear. Because each photovoltaic cell produces only about one-half volt of

electricity, cells are often mounted together in groups called modules. Each module holds about forty photovoltaic cells. By being put into modules, the current from a number of cells can be combined. PV cells can be strung together in a series of modules or strung together in a parallel placement to increase the electrical output. When multiple PV cell modules are put together, they can form an arrangement called an array or array field. In general, larger the area of a module or array, higher is the electricity produced. They can be connected in both series and parallel electrical arrangements to produce any required voltage and current combination.

At present India ranks first in usage of solar home lighting system (SHS) in rural areas, it has about 500,000 SHS and 700,000 solar lanterns distributed national wide [17]. Kerosene is used an traditional lighting fuel, even today about 100 million families depend on kerosene for domestic lighting [18], which offer poor light with low efficiency. The usage of electricity for domestic lighting provides 100 times more light than kerosene [19]; moreover the risk factor is also low while using electricity instead of kerosene. India uses very little amount of its solar PV systems to supply power to the grid in contrast to other countries which uses 75% of energy generated from PV systems to supply power to the grid. But this trend is facing a change with the launch of JNNSM by the Indian, many private companies are planning to develop solar PV power plants of capacity ranging from 1 to 30 MW capacity. Table 1 shows the list of solar power plants in India. And there are of about 30 more solar photovoltaic power plants of 5 MW capacity that are to be installed all over India, 90% of these plants are located in the state of Rajasthan, which is rich in solar energy. The main disadvantage of solar PV micro grid system is it's high capital cost, the solar PV array alone cost around 53% of the total cost of the system which includes PV array, battery bank (11%), power distribution network (16%) and power conditioning unit (20%) [20]. The cost of the power distribution network (PDN) varies depending upon topology, the cost of 400 V three phase low tension (LT) distribution line is Rs. 150,000 $km^{-1}$ for plain region and it increases by 10% and 25% in case of hilly region and remote villages [21]. Thus by only considering the fixed cost of the solar PV micro grid system (without including the distribution cost) the solar PV array alone accounts for 63% of total cost, battery bank (13%), and power conditioning unit (24%). But the cost of the solar PV arrays have declined from 158 $W^{-1}$ to 90 $W^{-1}$ in the past two years, which is a great boost for the PV market in India [22].

In India 18,000 villages which do not have access to electricity are located in hilly and remote areas [23], as the cost of transmission and distribution of power is high for such regions micro grid PV system is considered as a viable option for such regions. The main advantage of micro grid PV system is that it is noise free, pollution free, zero fuel, less transmission and distribution losses, highly durable (up to 25 year), requires less maintenance and self-reliant energy source. The production of 1 kWh of power using PV system prevents the emission of 0.7 kg of carbon dioxide [24]. But micro grid PV system is economically feasible only when a village of 180 household using two appliances (totaling18 W) for 4 h is serviced with 1 km of PDN. This number increases to 270 if the households are scattered such that 4 km of PDN is required to service them. On the other hand if 4 appliances are used by the households for 4 h each then a village of 100 households is serviceable with 1 km of PDN using micro grid, this number increases to 150 if the system requires 4 km of PDN. If a village does not satisfy the above-mentioned criteria then it is better to use SHS rather than micro grid system [25]. But the main disadvantage of SHS is its high capital cost; as on 2006 only 10%, 23% and 75% of people living in rural area households are able to afford for 37 W SHS, 20 W SHS and 20 W SHS respectively, in spite of finance offered by bank at 12% interest for five years [24]. But in case of micro grid PV system the user has to initially pay about 1000–2000 as installation cost and about 100–200 per month depending upon their power consumption. The risk involved with SHS system such as deep discharge of batteries and theft are eliminated while using micro grid system. 25–30 direct jobs and 5–15 indirect jobs are created for every installation 1 MW solar PV micro grid system [26,27]. But the main disadvantage of micro grid PV system is the huge land requirement for the construction of the system. It requires about 40,000 $m^2$ of land area to construct 1 MW capacity solar power plant, which may be otherwise used for agricultural purpose. Moreover the efficiency of the PV system decreases with increase in temperature of solar PV array, hence it is necessary to maintain the temperature of module at lower temperature this can be achieved by using solar water pumping system. It is found that the efficiency of the PV system increases by 15% during peak solar radiation because of the loss of heat energy on the surface of the solar panel by convection to cooling water [28]. The heat energy absorbed by the solar panel can also be used to heat air or water, in such cases the entire PV array is placed inside a transparent glass box and it consists of an absorber and heat transfer fluid (air or water) [29,30]. The hot air and water can be used for domestic needs; hot air can be used to dry cloths, agricultural and marine products [31].

The shortage of land for construction of solar PV power plants can be overcome by using PV system in roof tops, rocky outcrops and water spaces. To construct a roof top PV system, the roof must be made of strong materials like cement or reinforced concrete and have a plinth area of at least 75 $m^2$. In Kerala were most of the rural areas are located in hilly terrain have about 31% of its households with more than 75 $m^2$ plinth area and strong roofs. By accounting only 15% these total area for PV power generation about 267 MW power can be generated. In the same way about 1027.95 MW of power can be generated by using 10% of 411.18 $km^2$ of rocky outcrop area present in Kerala for PV power generation. The potential for PV power generation by using 15% of its water spaces is about 2151.91 MW in Kerala, but this technology is yet to hit the market and it is still in developing stage [32].

### 2.2. Storage device or battery

As solar energy is not available throughout the day the excess energy generated during sunshine hours must be stored to provide power during nights, this task is achieved by using batteries to store the energy. Batteries are devices which stores electrical energy in the form of chemical energy while charging and the reverse process happens during discharging. The batteries used for PV system are charged and discharged often; hence they are specially designed to meet the stronger requirements than regular batteries. It also helps to produce constant output from PV system where the input is often fluctuating [13]. The size of the battery must be such that it is capable of storing energy required for one complete night. The main disadvantage while using batteries for storage is its high capital cost but it decreases with increase in battery rating. Batteries are capable of discharging more current which is even higher than the current produced by charging source; hence it can be used to run motors and pumps immediately. Lead acid, nickel hydride, and lithium ion batteries are generally used in PV system; among these lead acid batteries is considered as most suitable for micro grid applications as it is capable of providing large current for a very short interval of time [33]. There are two types of lead acid batteries which are available in different sizes they are flooded and valve regulated lead acid batteries, while the flooded batteries last longer with proper maintenance the floored lead acid batteries require less maintenance but its life span is low [13]. The main advantage of lead acid battery is its low cost and its high safety and efficiency; but the life time (250–750 cycles) of these batteries are low and it has low specific energy [34].

**Table 1**
Solar PV power plants in India.

| Name of the plant | Company name | DC peak power (MW) | State were the plant is located |
|---|---|---|---|
| Patan Photovoltaic Plant | Lanco | 5 MW | Gujarat |
| Kolar Photovoltaic Plant | Titan Energy | 3 MW | Karnataka |
| Itnal Photovoltaic Plant | Photon Energy Systems | 3 MW | Karnataka |
| Jamuria Photovoltaic Plant | Titan Energy | 2 MW | West Bengal |
| Awan Photovoltaic Plant | Azure Power | 2 MW | Punjab |
| Thyagaraj stadium Plant | Reliance | 1 MW | Delhi |
| Chandrapur Thin Film Photovoltaic Plant | Moser Baer | 1 MW | Maharashtra |
| Keshavpuram roof top Photovoltaic Plant | North Delhi Power Ltd. (Tata Power) | 1 MW | Delhi |

The life of a battery in a solar PV system ranges from 3 to 5 years, its life span depends greatly on the load connected to the system, charging and discharging pattern, temperature and ageing properties. Among these temperature is one of the most important parameter which not only affects the battery life but also accelerates the ageing properties such as corrosion, sulphation, gassing and self-discharge with increase in temperature. The operation of the battery is at its best only when the temperature is maintained at 283–293 K, the life of the battery decreases by 50% for every increase in temperature by 10 K [34]. The batteries life span can be increased by optimizing its operating conditions; this task is achieved with the help of battery management system (BMS). The BMS system helps to protect the battery from over charge and deep discharge; it also helps to achieve charge control and battery state determination. The BMS disconnects the battery from the PV system when the available current is more than the maximum allowable charging current. It also protects the battery from discharge below 20% of battery storage capacity. The BMS is a part of power conditioning unit (PCU) which also includes inverter, junction box, distribution boards and wiring and cable requirements which are enclosed inside a building to protect it from atmospheric disturbances.

### 2.3. Inverter

The inverter is a device which is used to convert DC power generated by solar PV system into AC power to supply it to the load connected to the system. The voltage level at the supply end must be maintained constant by the inverter for effective operation of the load. The high generation of power by PV system during low load period may cause over voltage in low voltage distribution feeder when the power source is non-controllable. The system is usually protected from such high power by passively limiting the penetration level of PV to very conservative values. But by using active power curtailment (APC) techniques one can inject maximum power from the DC source, as long as the AC bus voltage is below a certain value but when this AC bus voltage level increases beyond certain value the injected DC power is curtailed linearly for every increase in AC bus voltage [35]. The main advantage of this system is that it requires only less modification in the distribution generation unit and the output power loss is also very low as it gets activated only when needed [36].

### 2.4. Power distribution network (PDN)

A power distribution network (PDN) consists of poles, conductors, insulators, wiring/cabling; service lines, internal wiring and appliances to individual households like compact fluorescent lamp, television, fan, radio, etc. [37]. The cost of the PDN plays a huge role while determining whether a micro grid PV system is economically feasible for an area or not. There are different types of PDN which are used according to the demand they are single wire earth return system, two wire single phase line and three wire three phase system. The cost of single wire earth return system is 50% and 70% lower than two wire single phase line and three wire three phase system respectively [38].

## 3. Financing rural electrification and the role of subsidies

It requires about 17 crores for the construction of 1 MW solar power plant [39], which is about three times the cost required for the construction of coal power plant of same capacity. Thus it requires about 12–20 for kWh of power generation by solar power plant [39]. Hence it is essential for the government to provide financial incentives and subsides to private sectors, which are coming forward to electrify the rural areas using PV micro grid system because rural area electrification using PV system requires a long term financing for about 15–20 years.

The Government launched a centrally sponsored scheme, "Rajiv Gandhi Grameen Vidyutikaran yojana (RGGVY) on 18.3.2005 with the goal of creating electricity infrastructure to all rural villages and hamlets in order to provide access to electricity to all households within 2012. This programme is funded by Government of India through Rural Electrification Corporation Ltd., New Delhi. 90% of the fund is given as subsidy and 10% as loan. Moreover 100% subsidy is given for effecting service connections to the Below Poverty Line House Holds (BPLHH). This scheme aims to provide decentralized distribution-cum-generation from conventional or renewable or non-conventional sources such as biomass, bio fuel, bio gas, mini hydro, geo thermal and solar etc., for villages where grid connectivity is either not feasible or not cost effective. Other villages will be connected to the grid by installation of transformers and distribution lines in appropriate areas.

Recently the central government of India approved 12 proposals under the Special Incentives Package Scheme (SIPS), which altogether cost around 76,573 crore to be used for domestic solar power sector. Under SIPS, the government provides 20% and 25% of capital cost as incentives for the first 10 years for units located inside special economic zone and united located outside special economic zone respectively. The incentives provided by the government under SIPS may be in the form of capital subsidy or equity participation.

The government of India provided subsidies worth of around Rs. 500 million for projects aimed at promoting the use of solar energy in rural areas. These subsidies are directly spent to the project related to solar home lighting and street lamps in villages across country.

### 3.1. Jawaharlal Nehru national solar mission

Indian government recently launched India's national solar mission which aims at installing 20,000 MW of solar power generation capacity by 2022. This project is to be carried out in three phases and an investment of about 91,684 crore is to be used for this project in the next 20 years. This project aims to promote rural solar energy programs across the country and also aims to bring down the cost of solar power generation so that it can compete with power generated using fossil fuel by the year 2017–2020 [40].

JNNSM targets both grid connected and distributed power generation systems. Funding will be on the basis of submission of a project report which would include client details, technical and financial details, operation, maintenance and monitoring arrangements. The project will be funded by a mixture of debt and equity, and the promoter's equity contribution must be at least 20%. The subsidy will be dispensed as a combination of 30% subsidy and/or soft loan bearing 5% interest. The subsidy percentage is calculated not as per real cost, but cost benchmarked by Ministry of New and Renewable Energy (MNRE), whereby the value of the subsidy, which is equal to 30% of cost of systems is estimated at Rs. 90 per Wp (with battery storage), and at around Rs. 70 per Wp (without battery storage). The benchmarked cost of standard solar systems will be revised every year. Standalone SPV plants with battery storage in micro-grid mode/local distribution network, to meet unmet community demand for power in rural areas which do not have access to electricity, will be provided a capital subsidy of Rs. 150 per Wp and soft loans at 5% interest rate. However, in for states like Sikkim, Himachal Pradesh, and Uttarakhand, a capital subsidy of 90% will be availed. Moreover, in difficult to reach areas such as Lakshadweep, Andaman and Nicobar Islands, and districts on India's borders, the subsidy availed will also be 90% for solar PV installations, but only 60% for solar thermal installations. 100% of real cost could be subsidized by the government in case of novel and innovative application of solar systems.

#### 3.1.1. JNNSM first phase problems

JNNSM which was unveiled by the Indian government to satisfy the rising energy demand of the country by harvesting solar energy has promised much but teething problems threaten to crash it. Debt financing of solar projects, irrational bidding, and small plant sizes of 5 MW, unhealthy competition and other problems have cropped up as a threatening problems for this issue. The biggest problem is that the winners of the Solar PV Projects are mostly unknown small firms who have bid so low that make the returns negative for investors according to the renewable energy ministry officials (MNRE). Bidding has gone as low as 23 c/Kwh which is very low considering the debt costs in India are as high as 13% annually. Even India's Tata Power says that the projects are not bankable as there is a confusion about how the electricity tariffs will go to developers, its difficult how these unknown firms could manage the financing. While the companies will lose their bid deposits if they don't finish the projects, Indian Solar Energy will be the biggest loser as the failure of the Phase 1 of JNNSM of 1000 MW by 2013 will lead to even further delays.

A preferential tariff of about 18.44 is provided by Central Electricity Regulatory Commission (CERC) for every unit of power generated by solar PV power plants for the next 25 years, which will be purchased by National Thermal Power Corporation (NTPC) Vidyut Vyapar Nigam. The tariff will be reviewed each year by CERC for new projects. The government offers zero excise duty for local manufactures of solar energy devices and systems. It also provides zero or concessional duty on import of certain items. Moreover the value added tax for PV systems is also low when compared to other products. The banks also offer loans for PV system with an interest lower than the market rate.

The Indian government started the Renewable Energy Certificate (REC) Policy on December, 2010, which allows green energy generators to earn additional tariff over and above the normal wholesale electricity price. The CERC has implemented many comprehensive policies to boost green energy generation one among them is it had earlier mandated a 6% renewable energy percentage from alternative energy which would go up to 15% by 2020.The REC policy helps to achieve those targets by providing a pseudo market linked mechanism to incentivize green power producers. The renewable energy generators are granted a REC per MWh of green energy that they contribute to the grid, which can be traded on exchanges by green energy traders to energy deficient entities. Energy deficient Entities have to buy these RECs in order to meet their renewable energy targets. Each state in India has a Renewable Purchase Obligation (RPO) which is decided by the State Electricity Regulator. RPO means that the State has to compulsorily consume a fixed percentage of electricity from Renewable Energy Sources. Some states in India like Tamil Nadu, Gujarat are rich in Green Energy while others like Bihar, Delhi and Maharashtra are deficient. Power Exchanges in India have already set the ball rolling in terms of trading in REC's. Renewable energy companies and green utilities are being benefited most from this Policy.

### 3.2. Financial implications

One of the focus areas on photo voltaic power plant is substantial reduction in the capital investment so that Photo voltaic power plant gets a better acceptance in the market among other power generation equipment. Approach will be towards providing minimum. Though there are a lot of variation in capital investment based capacity and suppliers average capital cost for photo voltaic power plant is around US $2000 per kWe installed capacity. Whereas conventional power plant and biomass power plants are at the order of US $500 per kWe. However the operation and maintenance cost is less or close to nil in case of photovoltaic power plant, the levelised annual cost is high due to higher capital. According to annual energy outlook [41] it is projected as an estimated cost of power generation by 2016 using Photovoltaic will be 21 cents per kilo Watt hour (kWh) by using photovoltaic power plant. Corresponding to the projection from conventional power plant will be 9–10 cents per kWh. These scenarios indicate that there is a need to reduce the capital investment at least by 50%, so that Photovoltaic power plant enters the energy market competing with conventional and other renewable energy based power plants.

## 4. Way forward

The drop in prices of PV system devices in the recent years and governments initiative to generate 20,000 MW of power by using solar energy within 2022 has opened up the market for PV investors in India. At present there are 11 domestic private solar module producers, 2 government owned solar producers and 3 foreign solar module producers in India. There are also 2 solar inverter manufacturers in India. But most of these investors were interested in SHS and solar water pumping system until recent years, it was only after the launch of JNNSM they started focusing on grid connected and micro grid PV system. Hence the government must carry out many R&D work in this field to bring out new innovations in low cost.

A technology reaches the masses only when everyone is aware of that technology. Hence to make people aware of this technologies PV system must be used in schools, colleges, bill boards, street lights, industries and shopping malls. Laws must be made such that schools, colleges, industries and shopping malls should meet 30% of their energy demand by PV system. This will not only help them to create awareness among people about the technology but it also makes them shift to energy efficient devices to reduce their energy demand. If they do not have enough space to install PV systems to satisfy their 30% energy need then must be asked to provide financing to generate the same amount of energy in rural areas which do not have access to electricity. The installation of PV panels in schools and colleges make students aware of such technology in the very young age, this may help them to bring out new innovations in this technology.

At present the Indian government offers subsidy to kerosene and cooking gas to make it affordable for the poor people of which 40% of kerosene is stolen to adulterate diesel used in locomotives. So the government must provide cash compensation for poor instead of subsidizing kerosene and cooking gas, this may triple the cost of kerosene and double the cost of cooking gas. But it will wipe out the revenue loss of about $15 billion dollar for state oil refiners and expose them to intense market competition in all oil products except diesel. This amount may be used to electrify rural villages, when the villages gets electrified the need of kerosene to provide lighting source gets eliminated. At present about 100 million families depend on kerosene for lighting purpose, thus by reducing the demand for kerosene about 22,000 crores can be saved each year, which is used to carry kerosene to these remote areas.

## 5. Conclusion

Thus from the above discussion it can be understood that the major reason for slow penetration of solar PV system is its high capital cost and low efficiency. Hence lot of R&D work must be carried out by the government in this field to find out an improved technology which operates at high efficiency and available at low cost. The above discussion also gives us the clear idea about various components of PV micro grid system and the economic feasibility of micro grid PV system in different topographies of rural area.

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